

“Via Lactea2” a billion particle simulation of the Milky Way’s dark matter halo

NCCS USERS MEETING



Juerg Diemand, UCSC
Project PI: Piero Madau, UCSC
March 27 2007

Project Overview

- **project participants**

PI: Piero Madau, UCSC

Marcel Zemp, Juerg Diemand, UCSC

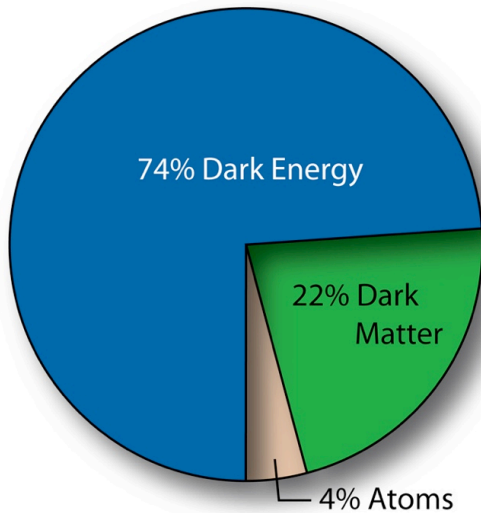
Mike Kuhlen, IAS Princeton

code development in collaboration with:

Joachim Stadel, Ben Moore, Doug Potter (Uni Zuerich)

- **short project summary, next 4 slides ...**

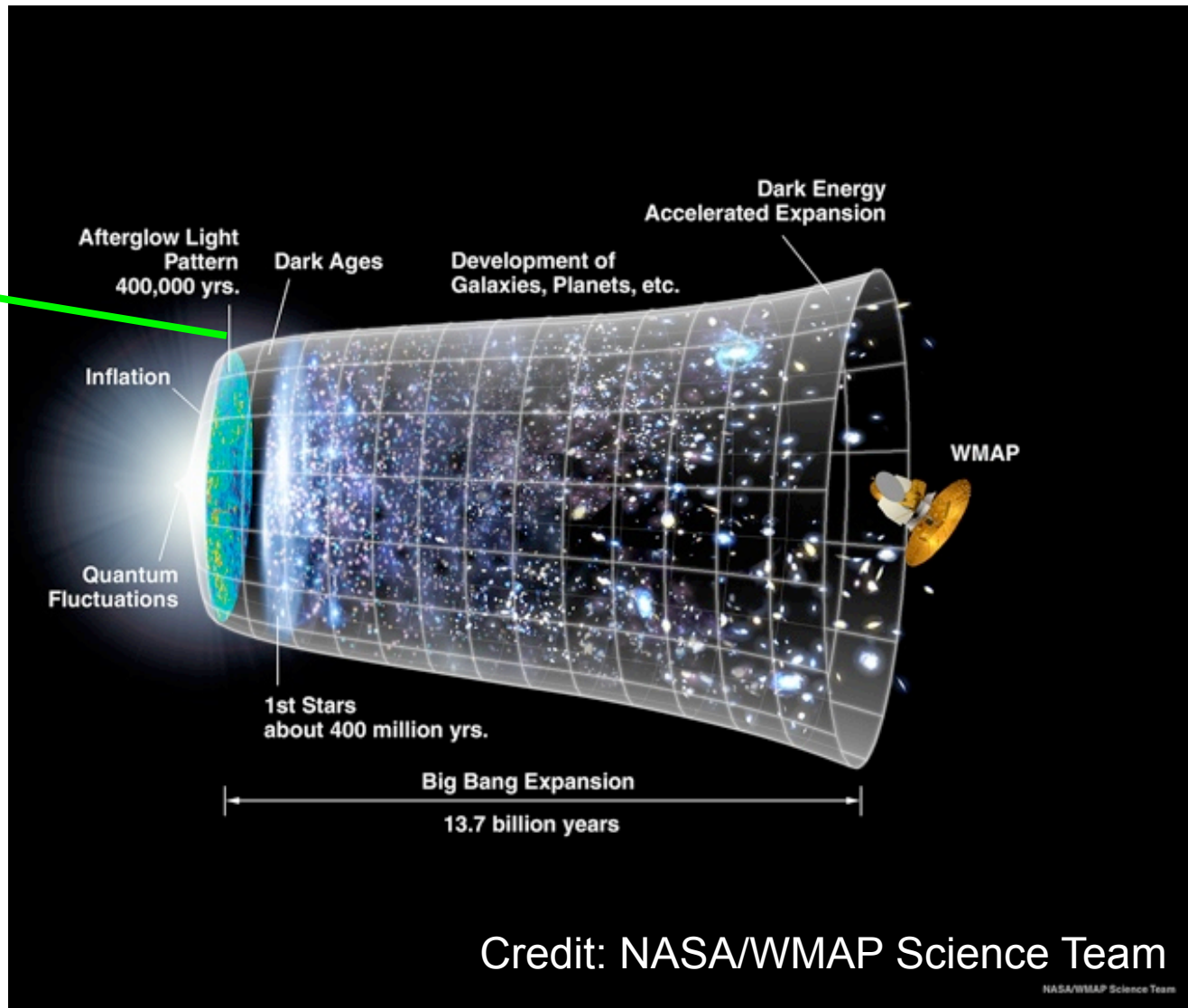
Project Summary: Dark Matter



Standard model of
Cosmology:

LambdaColdDarkMatter

dominated by dark energy
(smooth)
and cold dark matter
(forms structures)



Credit: NASA/WMAP Science Team

NASA/WMAP Science Team

Simulating structure formation

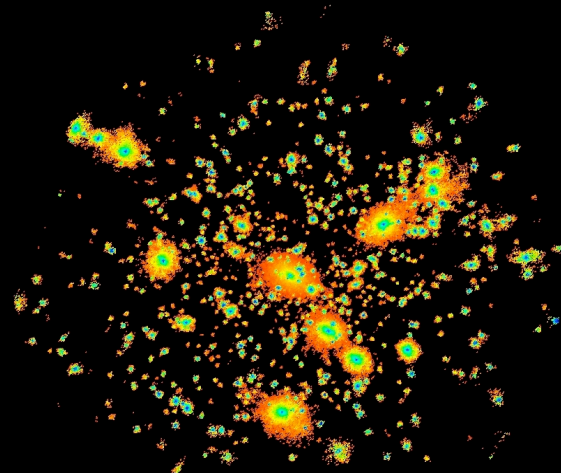
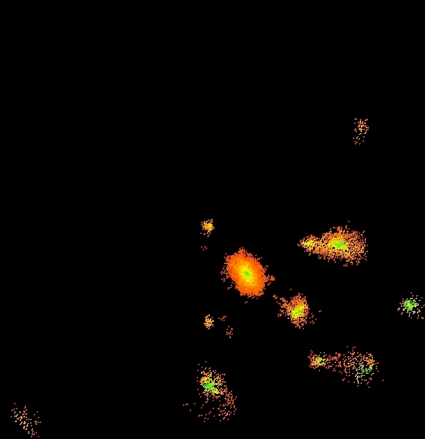
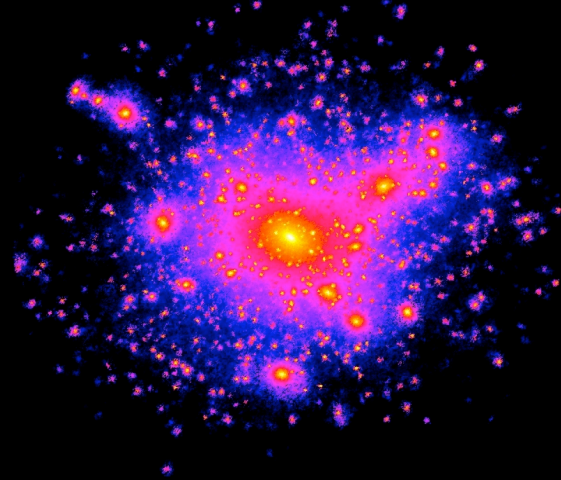
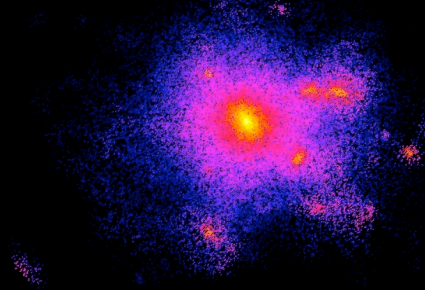
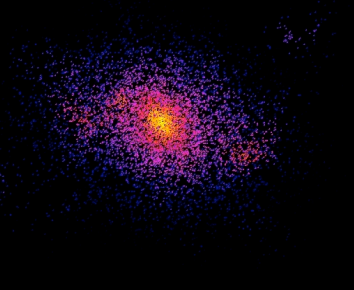
N-body models approximating CDM halos (about 1995 to 2002)

$N \sim 10,000$

100,000

1,000,000

log density



log phase space density

from Ben Moore : www.nbody.net

the “via lactea” simulation (2006)

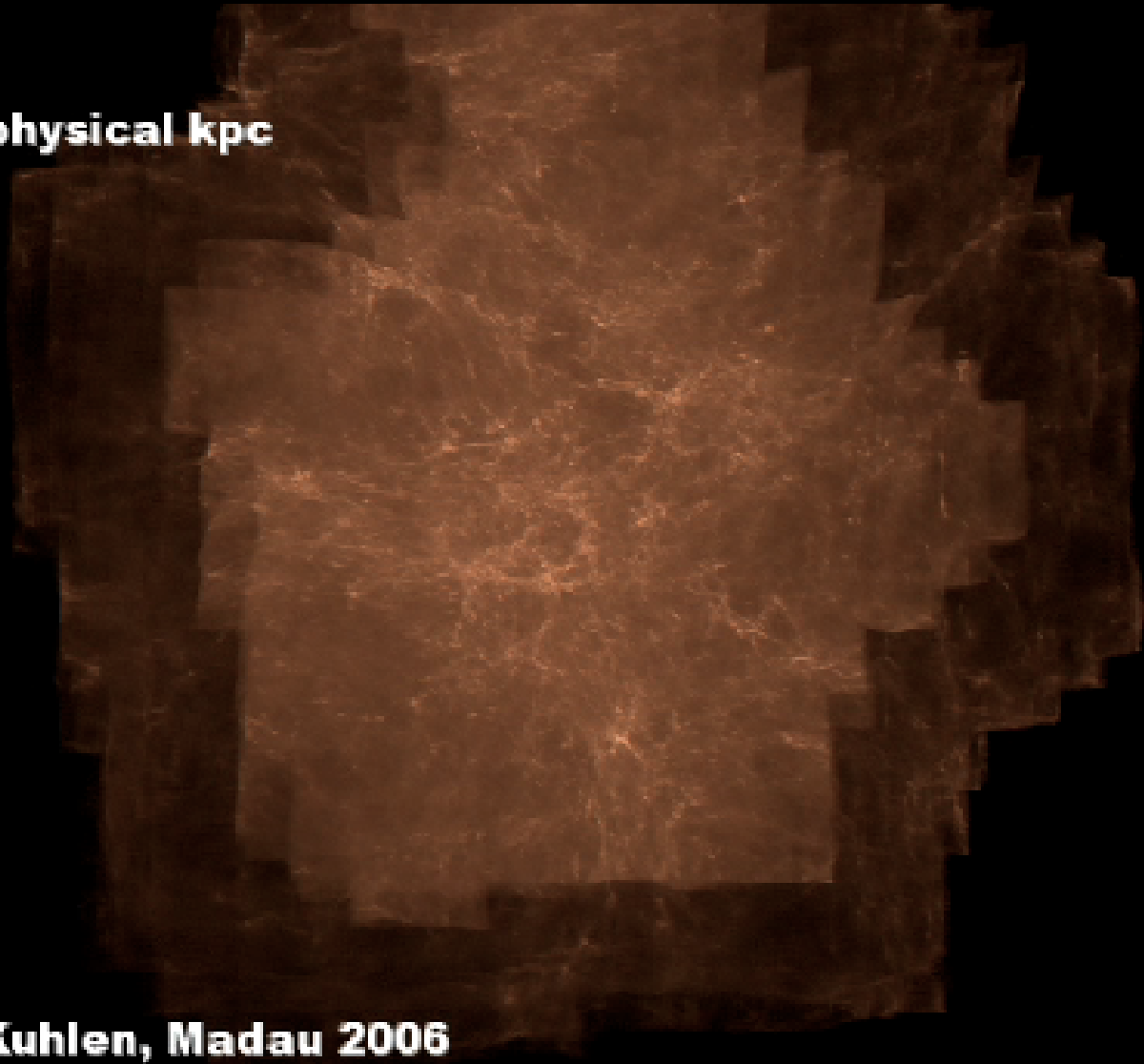
a Milky Way halo simulated with over 200 million particles

- collision-less (no hydro) ➡ accurate solution of an idealized problem
no free parameters, no subgrid physics
- largest DM simulation to date
320,000 cpu-hours on NASA's Project Columbia supercomputer
SGI Altix supercluster, with Intel Itanium 2 processors
- 213 million high resolution particles, embedded in a periodic 90 Mpc box
sampled at lower resolution to account for tidal field.
- WMAP (year 3) cosmology:
 $\Omega_m=0.238$, $\Omega_L=0.762$, $H_0=73$ km/s/Mpc, $n_s=0.951$, $\sigma_8=0.74$.
- force resolution: 90 parsec
- time resolution: adaptive time steps as small as 68,500 years
- mass resolution: $20,900 M_\odot$



$z=11.9$

800 x 600 physical kpc



Diemand, Kuhlen, Madau 2006

available from www.ucolick.org/~diemand/vl/

Project Overview: method & code

- PKDGRAV, MPI parallel tree N-body code

force calculation: direct $\sim N^2$

tree $\sim N \log(N)$

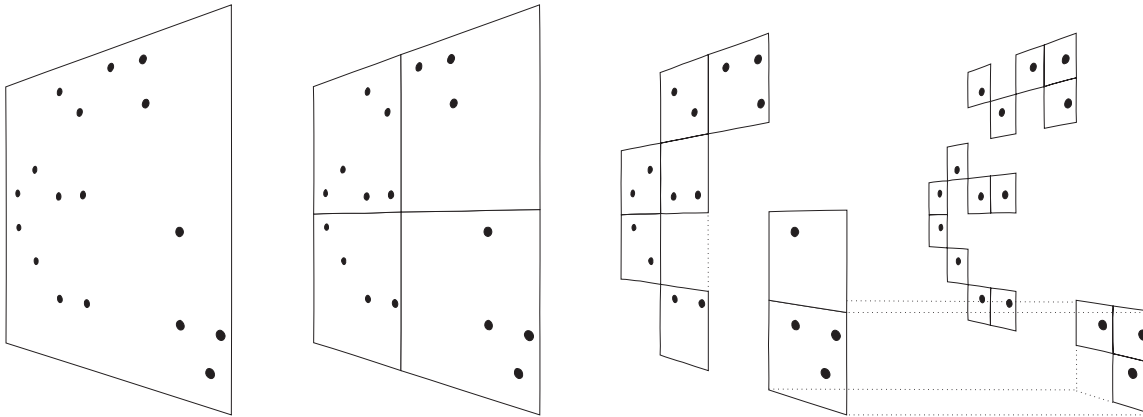


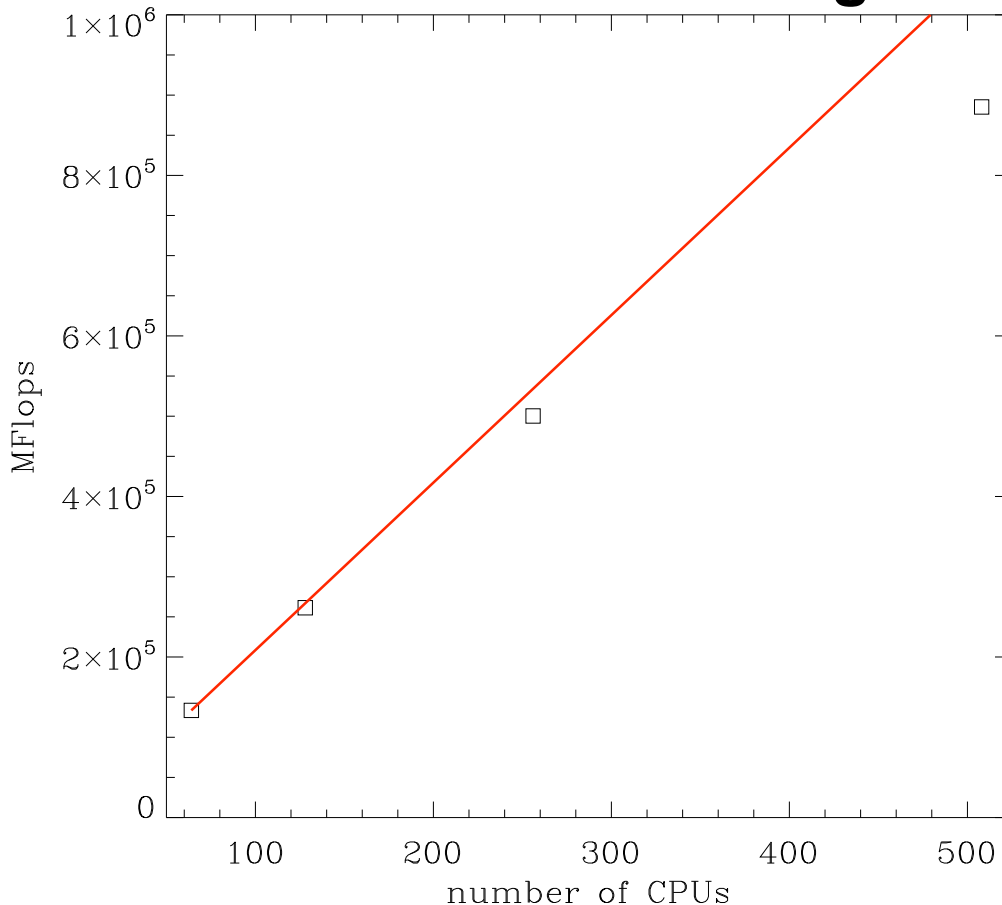
Figure 1: A schematic illustration of a Barnes&Hut tree in 2D. Image courtesy of Volker Springel.

same tree is used to divide up particles among the nodes

Project Overview: method & code

- PKDGRAV, MPI parallel tree N-body code

force calculation: scaling with #CPUs



on NASA Columbia

84% from 64 to 508 CPUs

~50 million particles

**goal for via lactea2:
more than 2048 CPUs**

Project Overview: milestones & timeline

- **generate initial conditions (JD, April 2007)**
- **improve and test simulation code (MZ&UniZH, May 2007)**
- **porting and testing code and start production run (June 2007)**
- **finish the run (fall 2007)**
- **first publication(s) and press release (end of 2007)**

Project impact

- **Most accurate model of the DM distribution around us**
- **Direct DM detection experiments (CDMS, DAMA, ...)**
- **Indirect DM detection (GLAST, HESS, MAGIC, ...)**
- **Near field cosmology, around Milky Way & Andromeda:**
 - mass in dwarf galaxies**
 - histories of dwarf galaxies (star-bursts, age, ...)**
 - stellar halos, stellar streams**
 - relics from the early universe (first stars, black holes)**

Project logistics

- one large production job: 1,500,000 CPU hours running on ~ 2048 CPUs
- requirements:

memory: ~ 300 GB

libraries : MPI

communication: interconnect latency (bandwidth is low)

data storage : 400 x 50 GB = 20 TB !

- special visualization needs:

we have some tools to create images and movies from these large 3D particle data sets

and are very interested in new methods/suggestions

Project logistics

- Ongoing minor development efforts:
 - eliminating all serial output
 - optimize adaptive time stepping
 - optimize parallel run time data reduction (halo finder)

**We are looking forward to an
exciting project with the NCCS !**